THE METEOROLOGICAL MAGAZINE

HER MAJESTY'S STATIONERY OFFICE

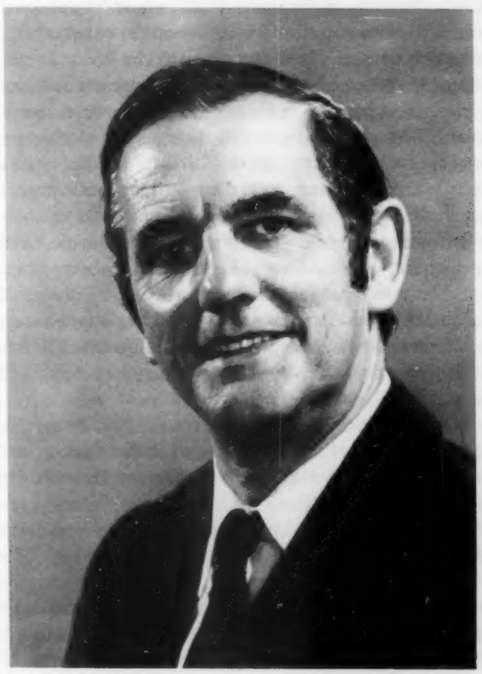
September 1983

Met.O. 958 No. 1334 Vol. 112

METEOROLOGICAL OFFICE Met. O.958

THE METEOROLOGICAL MAGAZINE

No. 1334, September 1983, Vol. 112



Photograph by G. A. Corby

Retirement of Sir John Mason CB, FRS

Sir John Mason retires from the Meteorological Office on 30 September 1983 after filling the post of Director-General for 18 years. His term of office was characterized by a remarkable range of major

developments and innovative changes, mostly accomplished as a direct result of his own enthusiastic drive and formidable determination to advance the interests and prestige of the Meteorological Office. Any regrets he may have on taking his departure can justly be tempered by the knowledge that he leaves behind a smooth-running and magnificently equipped institution which is truly in fine fettle.

John Mason came from Norfolk, as revealed to the sensitive ear by the lingering traces of an East Anglian flavour in his accent, and remained there until completion of his grammar school education. His academic training continued at University College, Nottingham, but was interrupted by the Second World War when he was commissioned and served in the Far East in the Radar Branch of the Royal Air Force. Returning from the war to London University, he graduated in physics with 1st class honours in 1947, later adding a London M.Sc. and D.Sc., and began a brilliant academic career at Imperial College amongst the stimulating group which included P.A. Sheppard, E.T. Eady, R.S. Scorer and F.H. Ludlam. In 1957 John Mason became the Royal Society's Warren Research Fellow and during 1959-60 visiting Professor of Meteorology at the University of California. After his return from the USA he was appointed Professor of Cloud Physics at Imperial College and established a group which under his leadership quickly achieved a high reputation for its scientific excellence.

By 1965, the year in which he was both elected a Fellow of the Royal Society and appointed Director-General of the Meteorological Office, John Mason was already internationally renowned in his specialized field of cloud physics. Apart from his overall eminence in the science he had become well known around the world for his courage and scientific integrity in challenging sensational but dubious claims of success in rain-making and by exposing questionable evidence or untrustworthy analysis. In consequence, he was often consulted (and still is) by those with power and influence who find themselves faced with awkward decisions in the controversial field of rain-making.

However, in the rather different and staid corridors of the Scientific Civil Service back in 1965, the newly-appointed Director-General of the Meteorological Office seemed to some a very youthful, even perhaps brash, successor to his sedate predecessors. If to be bold and audaciously imaginative is to be brash, then the description fitted: but events soon proved wrong any who may have feared a clumsy or incautious regime due to inexperienced direction. John Mason quickly established himself as a very shrewd scientific administrator and forceful organizer with a great capacity for getting things done and shaping circumstances for the benefit of the Office.

When he took over, the Meteorological Office was of course already an old-established and reputable institution. It had recovered from the traumatic effects of the enormous concentration on forecasting for military aviation during the Second World War; scientific research had been steadily expanded from almost nothing to a substantial total effort; and the Office was fully settled into its fine new headquarters at Bracknell. The white hope of forecasting, namely numerical prediction, was about to become a routine operational activity using the recently commissioned KDF9 computer (the Office's second large machine).

Of the countless achievements of John Mason's Director-Generalship the most significant have probably been the impressive enhancement of the material resources available to the Office, the many auspicious acts of reorganization and modernization introduced to meet changing requirements, the great emphasis placed on research both fundamental and practically oriented and, perhaps most important, a genuine heightening of the scientific standing of meteorology and the Meteorological Office.

The gains in material resources available to the Office have been considerable, for example: the giant computers such as the IBM 360/195 installed in 1971 (augmented in 1975 by the IBM 370/158 as a 'front-end' processor) and more recently the CDC Cyber 205, commissioned in 1981, which have provided massive computer power for both operational work and research and which have been the envy of many less fortunate meteorological services; the progressive automation over several years of

the Bracknell telecommunications centre; the striking improvements in accommodation as exemplified by the Richardson Wing at Bracknell which houses the main computers, telecommunications and Central Forecasting Office (incidentally the wing was formally opened by the Prime Minister, Edward Heath, in 1972), the splendid new building and facilities at the Experimental Site, Beaufort Park and the first-rate training college at Shinfield Park; also other outstanding assets such as the powerfully equipped Hercules aircraft of the Meteorological Research Flight and the fine facilities at Malvern for research in radar meteorology. Such costly resources are not bestowed at the drop of a hat by a benevolent Treasury. They have to be fought for through many stages of a sometimes lengthy bureaucratic process and the irresistible appeal of John Mason's persuasive advocacy has frequently been a decisive factor in securing the best possible for the Office.

Although John Mason encouraged meteorological research in universities, especially where they had some unique expertise to offer, he considered that inevitably the Meteorological Office had to be the primary seat of meteorological research in this country. Indeed, he believed with great conviction that the service-type activities undertaken by the Office would stagnate and fail to respond to new requirements unless good and appropriate research was vigorously pursued in parallel. Accordingly, he took steps to expand and develop the activities and projects on both the Services and Research sides of the Office whilst at the same time encouraging a healthy interchange of ideas and staff between the two sides, to the mutual benefit of both.

On the Services side a major organizational change was an additional Deputy Directorate for communications and computing created in 1970 to meet the paramount need for an organization like the Meteorological Office to make optimum use of the latest computer technology and potential in its operations and research. Additionally, extra emphasis was placed on the need to take into account the cost effectiveness of meteorological services and much effort was devoted to publicizing the benefits which could accrue in many industries and enterprises from an intelligent use of tailor-made meteorological advice and forecasts. Particularly relevant areas for these efforts were the North Sea oil and gas industries, Concorde operations and ship routeing services. As a result of these and many other efforts almost one third of the cost of operating the Meteorological Office is now recovered from customers of the various specialized services provided. On the equipment side a major development was the introduction into service of a new, automated radiosonde system of very advanced design, developed within the Meteorological Office.

As to research, John Mason established a new branch for research in cloud physics soon after taking office, whilst another new research group for specialized studies in geophysical fluid dynamics was subsequently set up and the effort in several areas was expanded, notably in numerical forecasting and in dynamical climatology (general circulation research). Major national projects were Scillonia and the Dee Weather Radar Project, whilst internationally during the 1970s the Global Atmospheric Research Programme (GARP) was steadily brought to fruition. An important landmark in the latter programme was the GARP Atlantic Tropical Experiment which John Mason personally promoted through his chairmanship of the International Board of Management and by committing substantial UK resources to the experiment itself, conducted in the tropical Atlantic in 1974. He also assiduously fostered satellite meteorology, in particular by conceiving and following up the idea of the UK contribution to Tiros-N and by applying his good scientific sense and statesmanship to furtherance of the Meteosat programme.

Reference to these international activities is a reminder that as Permanent Representative of the UK at the World Meteorological Organization (WMO), John Mason has, throughout his term as Director-General, been very active and influential in the affairs of WMO and many amongst the meteorological community around the world will sorely miss his presence and wise counsel at future Congresses and meetings of the WMO Executive Committee.

John Mason knew only too well that, given reasonable facilities, the excellence or otherwise of an organization like the Meteorological Office depends almost entirely on the quality of its staff. He rightly valued brains and scientific ability as of paramount importance. There is no doubt that around the universities of the country his many talks and lectures, delivered with his own special brand of infectious enthusiasm and given added magnetism by his own eminence, have done much to make meteorology an attractive discipline amongst the brightest science graduates and have resulted in a steady intake of high calibre staff which augurs well for the future of the Meteorological Office.

One might remark here that, although it may not have been evident to those who knew him only superficially, John Mason had a genuine concern for his staff and their welfare and was distressed when a staff member or his family was in trouble, perhaps from illness, bereavement or otherwise; however busy, he always felt impelled to offer what help or comfort lay within his power. Indeed, behind the brisk, extrovert exterior there is a kindly, sensitive inner man who likes to recharge his spirit occasionally by a solitary tramp over the countryside or by hearing an orchestral concert.

One would expect the task of managing the Meteorological Office to be so demanding and exacting that the Director-General would have no reserves of time or energy for other activities, but those who have worked close to John Mason will know that his drive, stamina and capacity for work are absolutely prodigious. He has always seemed to live and breathe science, especially meteorology, with an intensity which never flags and his work-style exemplifies perfectly the paradox that exceptionally busy people are the very ones who always appear able to take on even more!

To list all John Mason's extramural activities would take considerable space but we may perhaps mention as examples his substantial efforts over the years in support of the British Association for the Advancement of Science, culminating in his Presidency of the BA for 1982–83; his services as President of the Royal Meteorological Society, 1969–70 and as President of the Institute of Physics, 1976–78; his Chairmanship of the Council of the University of Surrey, 1970–75 and his acceptance of the Pro-Chancellorship of that University in 1979. However, his most significant contribution of this kind (and probably the one which has given him the greatest personal satisfaction) has since 1976 been his work for the Royal Society in his capacity as Treasurer and Senior Vice-President — an office which is by no means a mere sinecure but is a tough and responsible job, the performance of which decisively affects the scientific well-being of the country.

Throughout his career John Mason has also been a prolific contributor to the journals with some hundreds of scientific papers and articles to his credit, as well as the major textbooks on cloud physics and rain-making for which he is justly celebrated.

As a public speaker he is persuasive, eloquent and entertaining and naturally has always been in great demand. As well as undertaking many of the prestigious, commemorative lectures in the world of science (e.g. the Kelvin, Bakerian, Thomson, Hugh MacMillan, Symons, Halley, etc.) he has been tireless in his willingness to speak on any occasion which presented an opportunity to publicize meteorology or to promote the interests of the Meteorological Office. He has indeed been a splendid ambassador for the subject dear to his heart.

Not surprisingly the academic and scientific world has showered John Mason with honours and awards, for example the Charles Chree Medal and Prize of the Physical Society, the Rumford and Bakerian medals of the Royal Society, the Institute of Physics Glazebrook Medal, the Royal Meteorological Society's Symons Memorial Gold Medal and others, not to mention a number of Honorary Doctorates bestowed by universities anxious to show their esteem. The ultimate accolade, his Knighthood, came in the 1979 Birthday Honours List.

It is appropriate to make the point here that, in the writer's opinion, John Mason's wide-ranging commitments, far from lowering his effectiveness as Director-General of the Meteorological Office, did in fact enhance his contribution. Even the staff, to varying extents, basked in the reflected glory of their

illustrious chief's eminence and their morale was thereby enhanced. But, more important, the stature of the Director-General himself was strengthened amongst those with whom he had to deal in his official work, insofar as his scientific distinction ensured respect for his views and aspirations and gave added power to his elbow in the official business of the day, whether negotiating for resources or whatever.

It is of course well known that John Mason could on many occasions have moved on to pastures more green, more lucrative and more prestigious. Fortunately for the Meteorological Office, he had over the years come to have a special pride in, indeed affection for, the Office and undoubtedly he derived great pleasure and satisfaction from presiding over its welfare and progress. Happily these considerations won the day and were sufficiently strong to keep him in post as Director-General.

Apart from being a milestone for the Meteorological Office, the end of John Mason's term is naturally an important juncture in his own career but it surely cannot herald his retirement into oblivion, the very thought of which seems manifestly absurd. Whenever one meets him, he appears as ebullient as ever; whatever one discusses arouses keen interest and a shrewd comment; and if one touches a spot which is scientifically or meteorologically sensitive, the gleam in his eye is as fresh and bright as ever. Fortunately he also continues to enjoy undiminished energy for life and zest for work.

One can only conclude that there must be many spheres in which his unique talents, experience, judgement and leadership could be applied to good effect.

We wish him well in whatever new activity or challenge he takes up and hope that he will achieve great success and satisfaction. On a more personal level, we extend to Sir John and Lady Mason our sincere best wishes for all possible health, contentment and good fortune in the future.

G.A. Corby

Sir John Mason as seen by the Chairman of the Meteorological Committee

By The Earl of Halsbury, FRS

(Chairman of the Meteorological Committee, 1971–82)

From the start we met as experienced committee men in the field of scientific administration. Each of us knew what the other was supposed to be for. From the outset the relationship between Director-General and Chairman was established on a basis of doctrinal orthodoxy. All we had to do therefore was to get acquainted, make friends and discharge our functions without getting in one another's way.

Knowing it would be fatal, I never attempted to set up as an amateur meteorologist and was content to exploit my mathematical physics up to but not beyond the point where I could comprehend what the meteorological equations stated and thereafter take an interest in the difficulties in solving them by numerical methods. It seemed the least I could do by way of tribute to and interest in the work of my colleagues, and by pursuing it no further I was left free to admire the professional skill of John Mason in his own field, a skill that set the tone for all the work that went on under his overall command.

I shall never forget his brilliance as an expositor, first heard in the course of his Bakerian lecture at the Royal Society in 1971. I remember thinking how much I would like to emulate his quality when speaking in Parliament: fluent, word perfect and unhesitating without a note of any kind.

As an administrator he was the kind of tough, driving chief executive that every Ministry would like to see in post. As a policy-maker and decision-maker he was, in political terms, dry as opposed to wet: definitely not one of the bleeding heart brigade, he had no use for sob stuff or hard luck stories.

Granted that he had the confidence of his MinisTRY, what did the MinisTER need an advisory committee for? What was the function that we fulfilled that John could not discharge himself? Chiefly, I think, providing the Minister on occasion with informed lay views on problems with political, that is to say Governmental and Parliamentary overtones: for example, did such and such an activity give the tax payer good value for his money.

In order to enable us to weigh in with advice on demand, we had as a matter of routine to familiarize ourselves with the broad outlines of everything that went on by receiving regular reports, department by department and topic by topic in rotation. On these occasions we met the DG in another of his aspects, as compère waiting in the wings and intervening only occasionally to restore balance into whatever might be getting out of perspective in the cut and thrust of discussion.

I have left till the end a final aspect, that of friend. We got through twelve years work together without a disagreement or a misunderstanding. What else but friendship could emerge from such an association and what would life be without it?

551.509.311:551.509.313

A synoptic case-study using a numerical model

By E. McCallum, J.R. Grant

(Meteorological Office College, Shinfield Park)

and B.W. Golding

(Meteorological Office, Bracknell)

Summary

Conventional analysis is supplemented by results from a numerical model to give increased understanding of the airflow through a system causing an area of extensive frontal rain over England on 22 June 1982.

1. Introduction

The conventional approach in studying synoptic systems involves analyses of synoptic charts and tephigrams. The information gleaned by this approach is limited because the data, especially upper-air information, are rather sparse. Inclusion of radar and satellite data in the analyses has resulted in a greater understanding of the dynamics of these systems, but realistic evaluation of vertical velocity over a large area remains difficult. As mass ascent leads to cooling, condensation, clouds and formation of precipitation, it is essential to evaluate this parameter. This is possible by using a numerical model which can produce fields of vertical uplift derived from the basic equations of motion. Unfortunately, in most models the analysis and initialization procedures result in rather smoothed fields which are inadequate for detailed studies. This problem may be overcome by using forecast fields which are less smooth and have a better dynamical consistency of the mass and wind fields. However, the vertical velocities obtained in this way should be treated with caution since they are based on a model which imperfectly simulates atmospheric processes.

It is an object of this study to use both model and observational data in a complementary way to help in the understanding of the dynamics of a particular synoptic system. The observational evidence will be presented in the first part of the paper in the form of charts and diagrams. In the second part diagnostic fields and trajectories from a model forecast will be studied and compared with the 'conventional' findings. The particular synoptic system being investigated in this case-study occurred on 22 June 1982 and was responsible for widespread rainfall over large parts of England and Wales.

2. Synoptic analysis

During the period 21–23 June 1982 the upper-air pattern was dominated by a blocking anticyclone centred near Iceland (see Fig. 1). Cool air from northerly latitudes flowed over Scotland around this high pressure area, while further south a relatively strong zonal flow carried surface features from the Atlantic over France and southern areas of England. Two warm occlusions crossed southern England during 20–21 June, merged and became slow moving over the north Midlands (shown as OA on Fig. 2). This resulted in a quasi-stationary convergence zone over northern England separating the relatively cool dry air over Scotland from warm moist maritime air over southern England. Prolonged widespread rain fell in northern England on the 21st as a result of this area of convergence and consequential forced ascent.

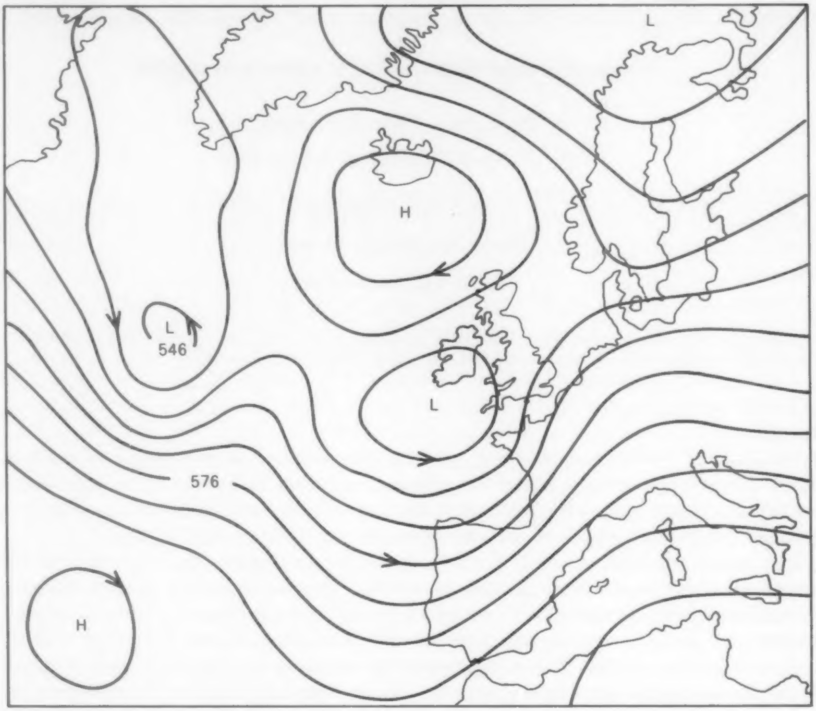


Figure 1. Contours at 500 mb (in standard decageopotential metres) for 1200 GMT on 22 June 1982.

On the 21st a deepening depression centred 250 nautical miles west of Corunna moved quickly north-east, ahead of a sharpening thermal trough, and was centred 80 nautical miles south of Ireland by midday on 22 June (see Fig. 2). At this time the vortex was moving north-eastwards at only 8 knots. The associated fronts swept across southern England during the morning of the 22nd, becoming slow moving near the line of the old occlusion OA later that afternoon. From detailed British Isles charts, radar data and satellite information it was calculated that at 1200 GMT the warm front WB and occlusion OB were moving north at 7 knots. Cold front CC over southern England was moving east at 17 knots while a second cold front or trough CD near Cherbourg progressed east at 22 knots. The infra-red satellite picture for 1355 GMT (Fig. 3) shows two parallel cloud bands curving down over France associated with the two cold fronts. CC represents the back edge of the extensive cloud mass and precipitation area, with generally lower cloud tops apparent on CD. However, the cloud on CD is enhanced in places by convective instability due to strong midsummer surface heating and local convergence. Otherwise, this second cold front is largely a low-level feature with little organized precipitation, but with a marked drop in surface dew-point behind it. The features of the two fronts exhibit similar characteristics to the split cold front model of Browning and Monk (1982).

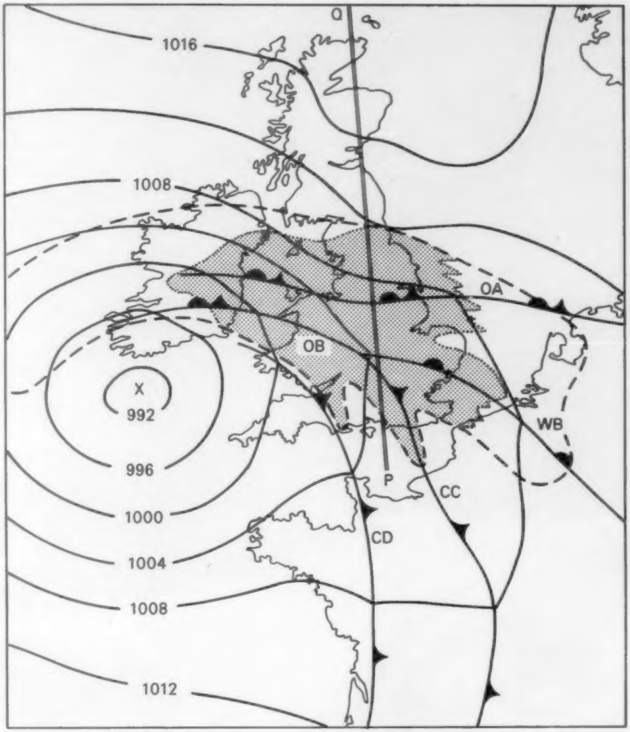
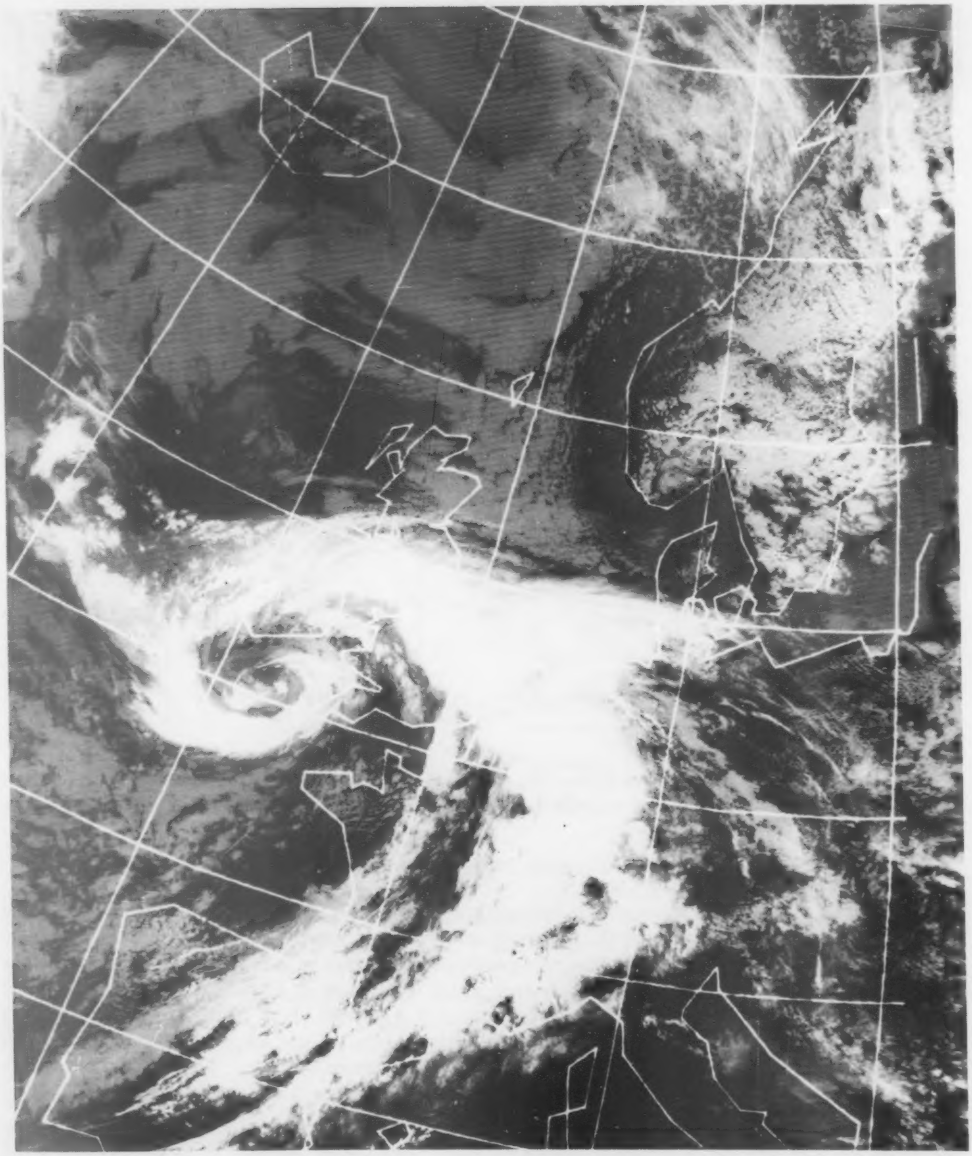


Figure 2. Surface analysis for 1200 GMT on 22 June 1982. The shaded area includes stations reporting moderate or heavy rain at the 1100, 1200 or 1300 GMT observation. The dashed line encloses the area of slight rain. The line PQ denotes the cross-section shown in Fig. 4.

A good deal of very warm moist air was brought north in the southerly flow ahead of these cold fronts and as this was forced to rise over the Midlands and northern England, large amounts of rain were produced. This warm front and occlusion rain reinforced the rain already falling in the old convergence zone, producing an extensive precipitation area which is depicted in Fig. 2. The heaviest and most persistent rain was in northern and eastern England with Silpho Moor in North Yorkshire reporting 94.2 mm in the 24-hour period commencing 0900 GMT on 22 June. Indeed seven other Yorkshire stations reported over 70 mm of rain that day with orographic enhancement adding to its intensity. The satellite picture (Fig. 3) shows the mass of cloud causing the rain over northern and eastern England as well as the swirl of cloud associated with the vortex south of Ireland.

A cross-section was taken almost north–south along the line PQ in Fig. 2, coinciding with the Pennine Chain (see Fig. 4). Examination of the values of wet-bulb potential temperature (θ_w) revealed a major frontal zone between 8 °C and 10 °C, having an average slope of 1:125. This was interpreted as an amalgam of the two warm occlusions which crossed the country on 21 June, and labelled OA on Fig. 2.



Photograph by Courtesy of Dundee University

Figure 3. Infra-red satellite picture for 1355 GMT on 22 June 1982.

The warm front arriving on the 22nd had θ_w values of 12 to 14 °C, but its structure was complicated by the presence of potential instability between 850 mb and 700 mb. The release of this instability in the form of 'generating cells' (see Marshall and Gordon 1957) was a major factor in the formation of enhanced mesoscale precipitation areas apparent on radar output.

For wind components parallel to the plane of the cross-section and relative to the motion of front OB/WB it is possible to estimate values of vertical motion if the following assumptions are made:

(a) air parcels maintained their own θ_w values.

(b) the thermal pattern of the front was unchanged.

This gives a band of ascending air over Aughton and Long Kesh, associated with the old occlusions, with maximum vertical velocities of around 8 cm s^{-1} below the 800 mb level. Another cell of rising air associated with the warm air behind front WB (θ_w 14 to 16 °C) is found above 600 mb over the Midlands with maximum uplift of around 12 cm s^{-1} at 400 mb. The calculated vertical velocity field below 700 mb between Hemsby and Long Kesh is complicated by the presence of potential instability. This highlights the difficulty of this approach and casts doubt on the results obtained.

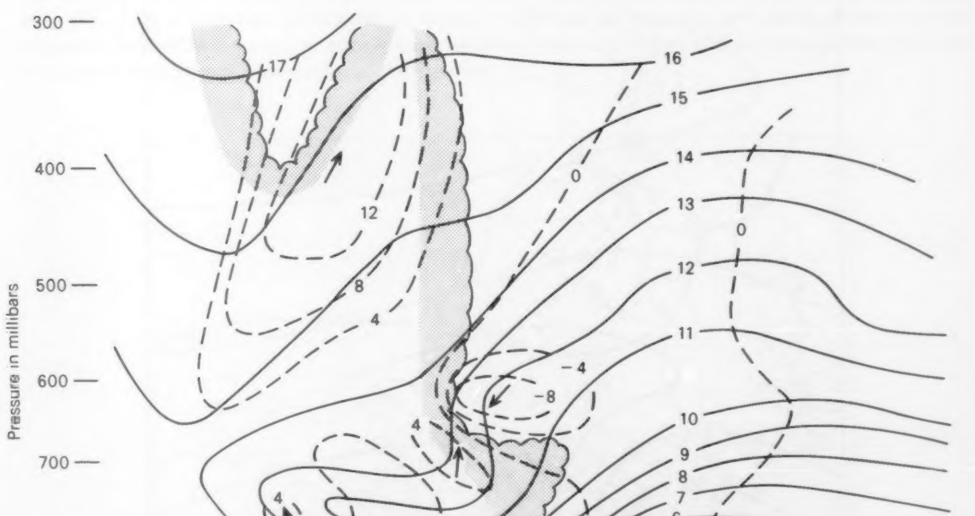


Figure 4. Cross-section along the line PQ shown in Fig. 2, for 1200 GMT on 22 June 1982. Solid lines represent wet-bulb potential values (θ_w) at 1 °C intervals. Dashed lines are isopleths of vertical motion in cm s^{-1}. The scalloped line denotes dew-point depression of less than 5 °C and is interpreted as the envelope of significant cloud. Station index numbers are shown above the radiosonde station names.

Fig. 5 shows a moist isentropic analysis (after Harrold and Nicholls 1968) based on midday data for the 14 °C wet-bulb potential temperature surface. This surface was taken as indicative of the movement of the warm air associated with front WB. The wind arrows represent airflow in knots relative to the front OB/WB and show the air rising up the isentropic surface over central southern England and the Low Countries. It was also found that analysis of the 8 °C θ_w surface showed general descent of the cool air at lower levels over Scotland and Northern Ireland.

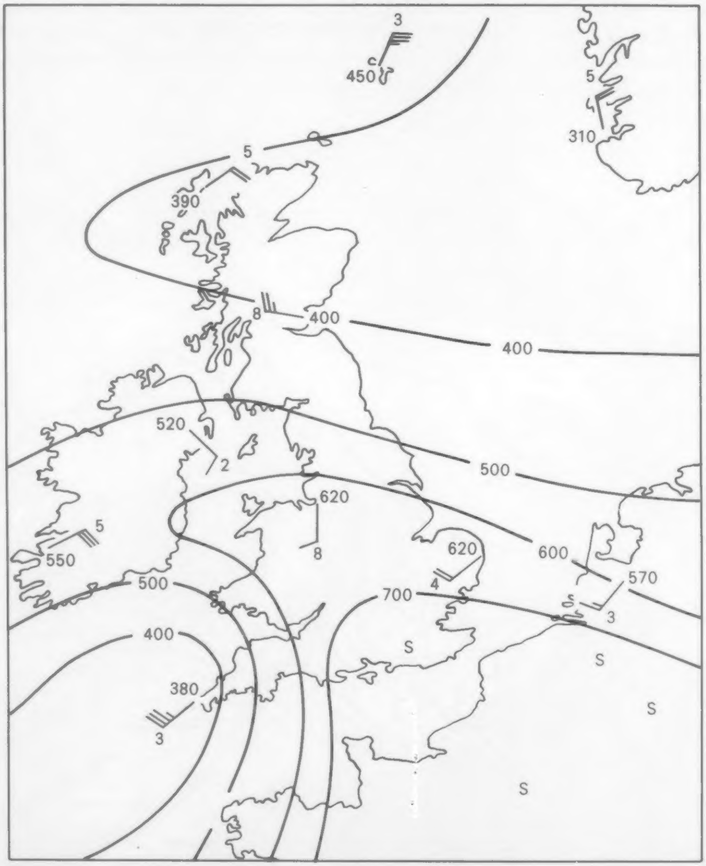


Figure 5. Moist isentropic analysis for the 14 °C wet-bulb potential surface at 1200 GMT on 22 June 1982. Solid lines show the height of the surface (mb). Stations with the surface at station level are marked S. Winds (kn) plotted at the radiosonde stations are relative to the motion of the warm front WB and are for the pressure levels (mb) shown.

3. Model simulation

The model simulation was made with the fine-mesh version of the Meteorological Office 10-level model (Benwell *et al.* 1971, Burridge and Gadd 1977, Gadd 1978a, b, 1980) which was in operational use at the time. The model has a 100 km grid length on a polar stereographic projection of the North Atlantic and western Europe. In the vertical, it has ten constant pressure levels at 100 mb intervals with the lowest at 1000 mb. The effects of orography are introduced through the 1000 mb geopotential tendency equation and by blocking the airflow where the surface intersects the lowest levels. The model has a comprehensive suite of sub-grid-scale parametrizations including condensation (leading to rainfall), solar radiation, surface fluxes of heat and moisture, surface friction and deep convection. Boundary values were fixed for the study presented here, but this did not affect results over the area of interest. The model has a time step of ten minutes; and contour height, wind velocity and humidity mixing ratio were obtained at every time step for use in trajectory and diagnostic computations.

The 12-hour model forecast for 1200 GMT on 22 June (see Fig. 6) produced a good qualitative description of the surface pressure field although the absolute pressure values were too high. However, the general shape and pressure gradient, important aspects from a forecasting point of view, were well represented. The area of moderate rain was also well predicted as can be seen by comparing Fig. 6 with Fig. 2. It is therefore reasonable to assume that since the forecast gave good guidance in this example, the model represented atmospheric processes reasonably well and so its diagnostic fields can be used to supplement observational information.

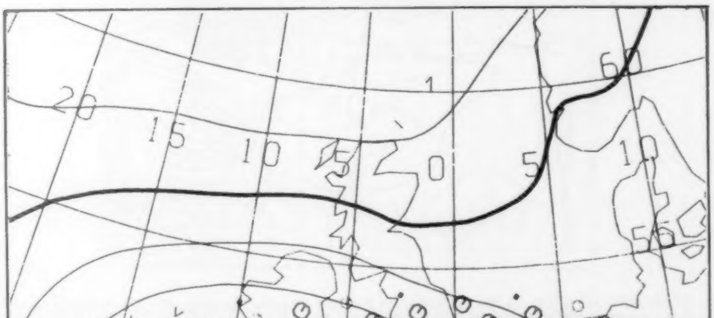


Figure 6. Twelve-hour forecast from the fine mesh version of the Meteorological Office 10-level model, valid for 1200 GMT on 22 June 1982. Frontal rain: ⊙ 0.5 to 4.0 mm h^{-1}, ⊙ 0.1 to 0.5 mm h^{-1}, o trace Showers: v 0.5 to 4.0 mm h^{-1}.

Fig. 7 shows the 500 mb vertical velocity field with a general area of uplift of 8 cm s^{-1} over the Midlands and a maximum of 13 cm s^{-1} at 51°N 3°E. This is at the junction between ascent in the conveyor belt ahead of the front CC and the general uplift associated with warm front WB, and corresponds to the steepest ascent noted in the isentropic analysis of Fig. 5. The region of ascent on front CC agrees well with the observed cloud in Fig. 3 and with the subjective analysis in Fig. 2. The effect of moisture plays a crucial role in the rate of vertical motion within the system. This is seen if Fig. 7 is compared with a corresponding dry run depicted in Fig. 8. The absence of moisture greatly reduces the vertical uplift with an innocuous 2 cm s^{-1} over the Midlands contrasting with 8 cm s^{-1} on the moist run.

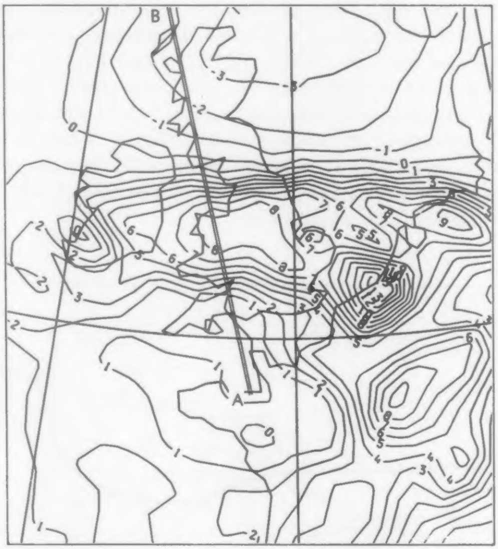


Figure 7. Twelve-hour forecast 500 mb vertical velocity in cm s^{-1}, valid for 1200 GMT on 22 June 1982. The line AB denotes the line of the cross-section shown in Fig. 9.

The vertical structure of the wet-bulb potential temperature field from the model forecast is shown in Fig. 9. The cross-section is taken along the line AB in Fig. 7 which is close to the line of the manual analysis shown in Fig. 4. The location of the strong θ_w gradient and its slope agree well between the diagrams, although the low-level values are generally two degrees higher in Fig. 9 with a weaker contrast between Hemsby and Aughton. Higher up there is some evidence of the double structure analysed in the hand-drawn section, shown by the space between the 12 °C and 13 °C isentropes in the Shanwell to Stornoway section. The model forecast only hints at an area of potential instability at 700 mb between Hemsby and Aughton compared with its conspicuous presence in the hand-drawn section.

Also shown in Fig. 9 is the vertical velocity from the model forecast, dominated by a cell of maximum ascent (almost two grid lengths wide), leaning northwards with height. This area of ascent corroborates the vertical velocity field obtained from the conventional analysis and corresponds well with the area of thickest cloud depicted in Fig. 4. The edge of the thickest cloud also fits closely with the zero vertical

isotach (in both the conventional analysis and the machine forecast) which separates rising air over England from sinking air over Scotland. This is supported by the satellite picture which shows the edge of the significant cloud over the Borders.

Airflow through the system is illustrated by examining trajectories of air parcels which show the air motions relative to the ground. A detailed description of the method and its application to the study of baroclinic wave development has been given by Golding (1981). In Fig. 10 the 1200 GMT positions at 950 mb are marked by dots, while the arrowheads show the position 12 hours later, with the final pressure level printed alongside.

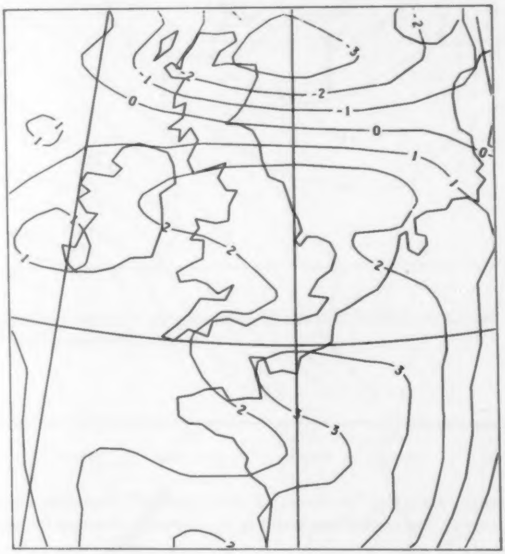


Figure 8. Twelve-hour forecast 500 mb vertical velocity, without moisture, in cm s^{-1}, valid for 1200 GMT on 22 June 1982.

To get an idea of the motion of the air over a 24-hour period reverse trajectories were also computed. Fig. 11 is an attempt to represent the low-level airflow at 1200 GMT in a simplified schematic manner with rising air shown by thickening arrowheads and descending air by arrows which thicken towards their tails. Two regions of flow can be identified. In the north, parcels move westward and descend slowly. In the south, parcels initially move northwards but on reaching the front they ascend rapidly and turn to the left to flow westwards above air from north of the front. This pattern is typical of the mature warm fronts analysed by Golding (1981).

Fig. 12 represents the flow of air at 750 mb for 1200 GMT. A gross distinction can still be drawn between ascent in the south and descent in the north. A further general division may be made into parcels which ultimately travel westwards and those which travel eastwards. Within the area of ascent there is considerable variation in intensity and two regions are marked within which parcels ascend very rapidly, many having an average vertical velocity greater than 4 cm s^{-1} over 12 hours or more.

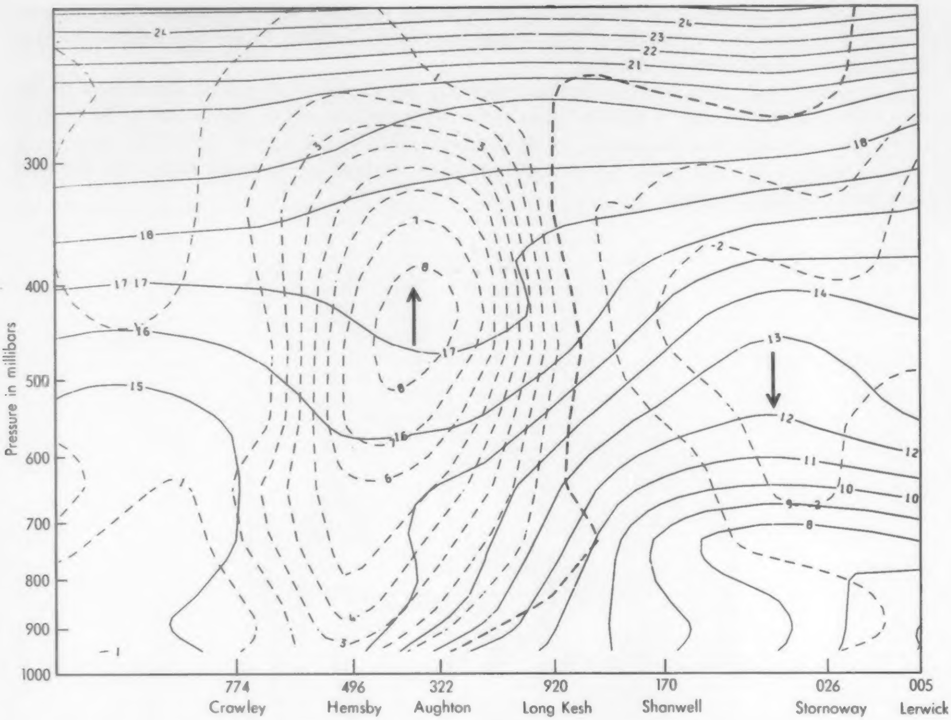


Figure 9. Cross-section along the line AB in Fig. 7 at 1200 GMT on 22 June 1982. Solid lines are wet isentropes in °C and dashed lines mark vertical velocity in cm s^{-1}. For comparison with Fig. 4, radiosonde locations are marked at the bottom along with their station index numbers.

At 450 mb (Fig. 13) the pattern is similar except that the demarcation line between eastward and westward flow lies further west. The most striking feature is the sharp discontinuity between rapidly rising parcels from the south and non-rising or sinking parcels from the north. The only area of disagreement with Fig. 5 is in the south-west, where the computed trajectories show parcels ascending rapidly during north-eastward motion and then turning westwards over Wales, whereas the isentropic analysis at this particular level shows descent. This is because the motion of this part of the system (the eastward moving front CD) was not taken into account in the hand analysis. This highlights a danger of isentropic analysis when the motion of the complete system is complex.

Fig. 14 is a cross-section from the model forecast along the line AB in Fig. 7, for the 24-hour period from 0001 GMT on the 22nd to 0001 GMT on the 23rd. The initial and final positions of the parcels are denoted by arrowtails and arrowheads respectively. The most striking feature is the narrowness of the band of parcels involved in the cell of strong ascent. Comparison of Fig. 14 and Fig. 9 indicates that parcel trajectories rise less steeply than the isentropes, although studies of 0600 and 1800 GMT model data confirm that the parcels conserve their θ_w values. This apparent discrepancy is accounted for by minor changes in the θ_w pattern itself and is largely due to the slow northward movement of the warm front.

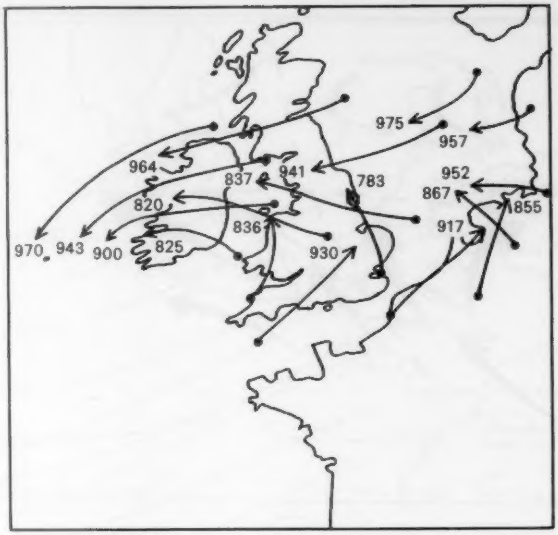


Figure 10. Twelve-hour trajectories for parcels of air initiated at 950 mb at 1200 GMT on 22 June 1982. Arrowheads mark the final positions with the pressure (mb) indicated alongside.

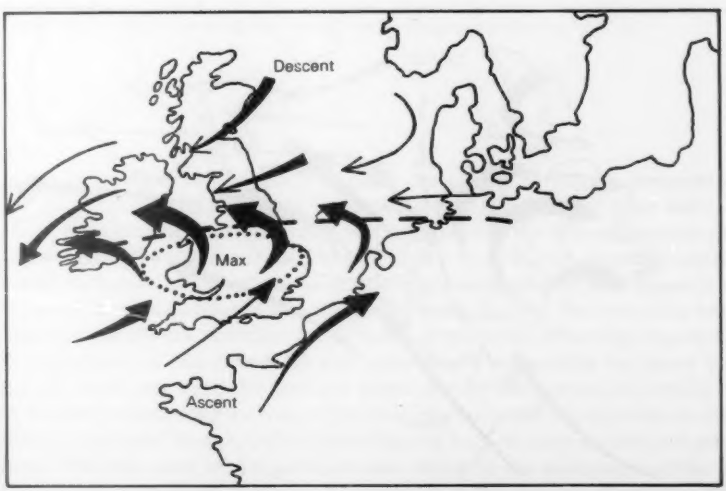


Figure 11. Schematic diagram of the airflow near 950 mb at 1200 GMT on 22 June 1982. Rising air parcels are indicated by arrows which thicken towards their heads and descending parcels by arrows which thicken towards their tails.

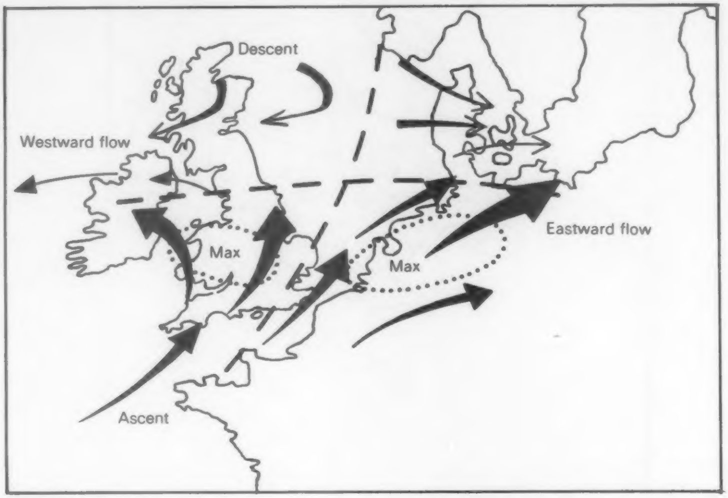


Figure 12. Schematic diagram of the airflow near 750 mb at 1200 GMT on 22 June 1982. Rising air parcels are indicated by arrows which thicken towards their heads and descending parcels by arrows which thicken towards their tails.

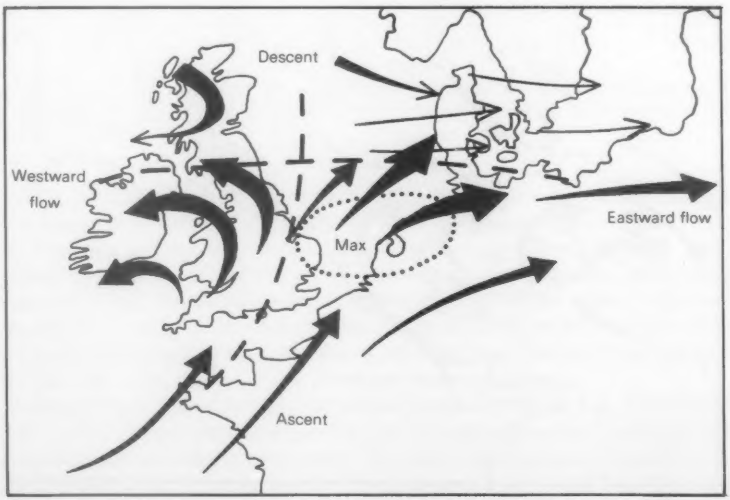


Figure 13. Schematic diagram of the airflow near 450 mb at 1200 GMT on 22 June 1982. Rising parcels are indicated by arrows which thicken towards their heads and descending parcels by arrows which thicken towards their tails.

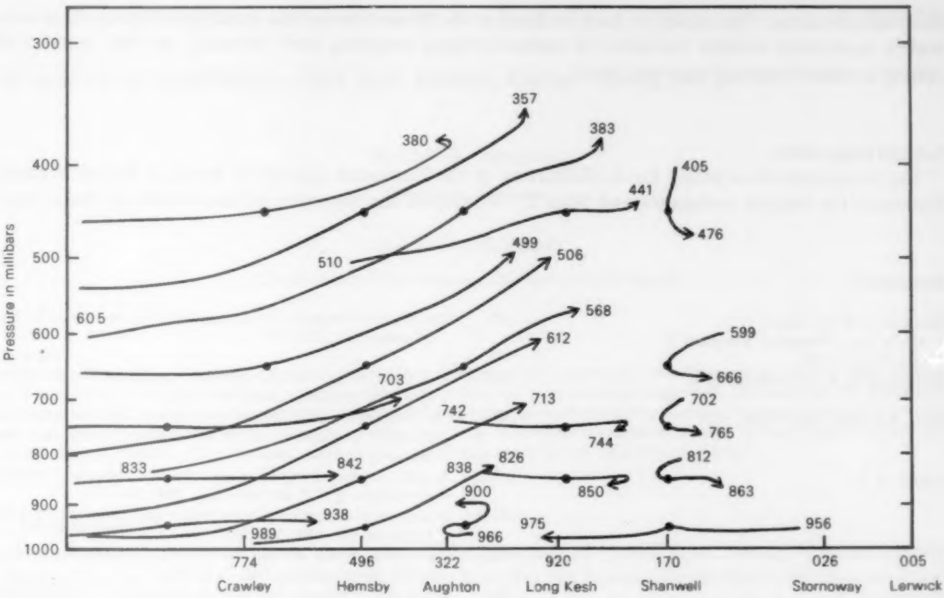


Figure 14. Twenty-four hour trajectories in the plane of the cross-section in Fig. 9. Positions at 1200 GMT on 22 June 1982 are marked by dots while the start and finish points have appropriate arrows with the pressure (mb) marked alongside. Radiosonde stations, with their index numbers, are marked at the bottom for comparison with Fig. 4.

4. Conclusion

An attempt has been made in this article to study the airflow through a synoptic scale system, responsible for widespread rainfall over a large part of England on 22 June 1982. From both conventional hand drawn studies and model data, it is apparent that the main mechanism producing the rain was the mass uplift of warm moist air from the south over cold air covering northern Britain.

The results from the numerical model emphasize the importance of latent heat release in substantially increasing the vertical motion compared with that found in the dry run. However, they fail to highlight the intricate detail of the system including the presence of potential instability depicted in the hand-drawn study. The release of this instability was undoubtedly responsible for heavy bursts of rain reported within the main rain band. Its presence made manual calculations of vertical velocity even more difficult, probably accounting for some of the discrepancy in the absolute values obtained by the different methods. In general though, the regions of ascent both in cross-section and plan view show good agreement. The only area of disagreement was found in the south-west of the UK and this emphasizes the difficulty of moist isentropic analysis when the motion of the complete system is complex, as is often the case.

These results supplement each other in aiding our meteorological understanding of this particular system. The model enables flow patterns to be visualized in a way which would be impossible using

observations alone. This ability to look in detail at the three-dimensional structure of synoptic systems makes numerical models valuable in meteorological teaching and research, as well as in their conventional role as a forecasting tool.

Acknowledgements

The authors wish to thank Dr R. Riddaway of the European Centre for Medium Range Weather Forecasts for helpful comments and Miss D. Woodcock for typing numerous drafts of this article.

References

Benwell, G.R.R., Gadd, A.J., Keers, J.F., Timpson, Margaret S. and White, P.W. 1971 The Bushby-Timpson 10-level model on a fine mesh. *Sci Pap, Meteorol Off,* No. **32**.

Browning, K.A. and Monk, G.A. 1982 A simple model for the synoptic analysis of cold fronts. *Q J R Meteorol Soc*, **108**, 435–452.

Burridge, D.M. and Gadd, A.J. 1977 The Meteorological Office operational 10-level numerical weather prediction model (December 1975). *Sci Pap, Meteorol Off*, No. **34**.

Gadd, A.J. 1978a A split explicit integration scheme for numerical weather prediction. *Q J R Meteorol Soc*, **104**, 569–582.

1978b A numerical advection scheme with small phase errors. *Q J R Meteorol Soc*, **104**, 583–594.

1980 Two refinements of the split explicit integration scheme. *Q J R Meteorol Soc*, **106**, 215–220.

Golding, B.W. 1981 Diagnostic studies of mid-latitude depressions. (Unpublished, copy available in National Meteorological Library, Bracknell.)

Harrold, T.W. and Nicholls, J.M. 1968 An investigation of air motion in frontal precipitation. *Sci Pap, Meteorol Off,* No. **29**.

Marshall, J.S. and Gordon, W.E. 1957 Radiometeorology. *Am Meteorol Soc, Meteorol Monograph* **3**, No. 14, 73–113.

551.593.653(4)

An analysis of noctilucent cloud over western Europe during the period 1966 to 1982

By D.A.R. Simmons
(Milngavie, Glasgow)
and D.H. McIntosh
(Department of Meteorology, University of Edinburgh)

Summary
A statistical analysis of noctilucent cloud observations received at the Edinburgh Data Centre from 1966 to 1982 shows a somewhat higher elevation for the upper border of the clouds than has been previously suggested. The range in solar depression over which the clouds were visible and their distribution in latitude are more restricted than in earlier surveys. The median date for peak frequency of occurrence of the clouds is found to be 4 July. An inverse relationship between annual sunspot number and corresponding frequency of noctilucent cloud occurrence is suggested but not definitely confirmed.

1. Introduction

Noctilucent cloud is an upper atmospheric phenomenon of considerable beauty most frequently observed during the long summer twilight of high latitudes. Such clouds form close to the mesopause at a height of about 82 km when the conditions of temperature and humidity are favourable. However, they do not become visible until obliquely illuminated by sunlight from below the horizon and, even then, only when the solar depression lies within the critical limits of 6° and 16°. The 1962 discovery that noctilucent clouds are largely composed of ice crystals (at heights where the water content had previously been judged to be too low for cloud formation) caused a resurgence of interest in this phenomenon that led to the setting up of World Data Centres around 1964. In this review we analyse and summarize the observational data that have been lodged with the West European Centre in Edinburgh and have been published in the form of annual reports, first by Paton (1967 to 1973) and subsequently by McIntosh and Hallissey (1974 to 1983). It is particularly appropriate to make this summary at the present time as the work of the Data Centre has just been concluded. For a comprehensive résumé of experimental and theoretical aspects of noctilucent cloud, in contrast to our summary of observational data, the reader is referred to the recent excellent review by Gadsden (1982).

2. The observational data

The data for this survey came from the annual reports of the West European Data Centre in Edinburgh for the period 1966 to 1982 (cited above) during which full observational information is available in respect of

(i) date and time of observation,
(ii) individual observer's latitude and longitude, and
(iii) maximum elevation of the cloud in the direction of the sun at the time of observation.

The corresponding reports for 1964 and 1965 were omitted from this survey because they contained insufficient detail to allow for corroboration.

A total of 1680 observations with the above information were received in this 17-year period; a further 126 incomplete reports were also received, but these were rejected for inclusion in this study as

they did not contain sufficient information for the mathematical criteria of acceptability to be applied. Each of the complete observations was screened for reliability by determining if it satisfied the conditions necessary for the illumination of noctilucent cloud from the observer's site at the time of the observation. This was done by testing whether the observed maximum elevation of the cloud (h), the solar depression at the time of the observation (d) and the height of the cloud (H) satisfied the mathematical relationship between these three interdependent parameters and whether the resulting values of d and H lay within the ranges normally accepted for noctilucent cloud. The details of the procedure, which is a modification of the 'one-sided' methods of Jesse (1885) and Bronshten and Grishin (1976), have been described by Simmons (1977).

On the basis of the derived heights, the observations were divided into three groups. The first group, with height values within one standard deviation (1 SD) of the average for all 1680 reports, numbered 1053 (62.7% of the observations). These are regarded as being of high reliability as all had values for h, d and H that lay within the accepted ranges. The second group, with H values between 1 and 3 SD of the average, numbered 540 (32.1% of the total). These observations would appear to be of doubtful reliability because their H values (and sometimes their d values) lay outwith the accepted ranges. The remaining group contained 87 (5.2% of the total) observations. Their height values differed from the average by more than 3 SD which implies that they are 'outliers' of poor reliability. When the high reliability observations were related to their dates of occurrence, it became apparent that multiple reports on a single night were common which tends to confirm their authenticity. In contrast, many of the observations classified as being of doubtful or poor reliability were single, uncorroborated reports, some occurring at the extremes of, or even outwith, the noctilucent cloud season. These findings taken together suggest that the criteria adopted enable one to assess the reliability of the observational data with some degree of confidence. In this report we shall be mainly concerned with the high reliability reports except where comparisons with those of doubtful or poor reliability enable some significant conclusion to be drawn.

3. Survey of noctilucent cloud in the years 1966 to 1982

(a) *Apparent elevation of noctilucent cloud*

There is now a considerable body of observational evidence to the effect that noctilucent cloud is a phenomenon occurring during nautical twilight, with most of the illuminated cloud in the twilight segment of the sky. It therefore follows that the clouds are most frequently seen at low elevation along the northern horizon. This view is substantiated and measured quantitatively in Fig. 1 which shows the distribution of our high reliability observations with elevation (in 5° zones from the horizon to the zenith); 411 (39.0%), 797 (75.7%) and 914 (86.8%) of the observations lay within 10°, 20° and 30° of the horizon respectively. In only 14 (1.3%) of the reports (not shown in the histogram) were the clouds seen to cross the zenith into the southern sky. Indeed, as a rough approximation, the incidence of the clouds may be said to fall off exponentially from the horizon to the zenith. However, an exception to this generalization is seen in the 0° – 5° zone, which has a small number of observations, attributable to the obscuring effects of dust, haze and tropospheric cloud in the lower atmosphere.

When all the observations were analysed, it was found that the percentage of those of doubtful or poor reliability in each 5° zone increased with their apparent elevation. Although there was some scatter due in part to differences in the sample sizes, the 'best-fit line' showed a progressive and steady increase from 29% of doubtful or poor reliability results in the 0° – 5° zone to 68% in the 85° – 90° zone. The precise reasons for the doubtful reliability of individual observations remain indeterminate from a general analysis of this type. However, a small number are almost certainly due to recording and

observational errors whereas the majority would seem to be attributable to difficulty in determining the maximum elevation of the cloud perhaps, for example, by confusion with concomitant tropospheric (cirrostratus) cloud. In the observations of high elevation, the increase in the doubtful reliability results may be explained as a compounding of these errors with the well-known difficulty of estimating angular elevation as one approaches the zenith. These conclusions prompt us to suggest that, if further surveys of noctilucent cloud are to be undertaken, greater attention should be given to 'fixing' the upper border of the cloud in the direction of the sun and to the introduction of better methods (photographic and instrumental) for measuring elevation.

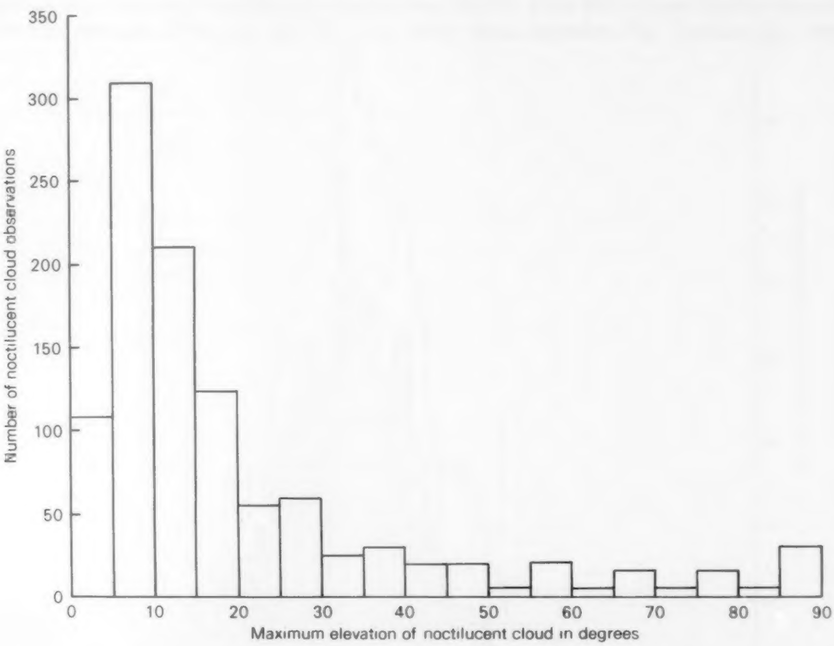


Figure 1. The incidence of noctilucent cloud at different elevations, in 5° zones between the northern horizon and the zenith. Fourteen reports of noctilucent cloud in the southern sky are not recorded in the histogram.

(b) *Solar depression and noctilucent cloud*

The solar depression can be determined accurately for any instant during a display given the observer's geographical coordinates and the date and time of the observation. Fig. 2 gives the incidence of noctilucent cloud at 0.2° intervals between 0° and 18° of solar depression for the 17-year period under review. The upper 'curve' shows the distribution of all observations including those of doubtful and poor reliability whereas the lower 'curve' shows the distribution of those of high reliability (i.e. with height values within 1 SD). The average solar depression from the lower, high reliability curve is 10.45° (corrected to the upper limb but not for atmospheric refraction) which is in good agreement with the

generally accepted view that noctilucent cloud is maximal in frequency and brilliancy when the sun is about 10° below the horizon. It will be noted that not one of the 68 observations made when the solar depression was less than 6.2° passes our liberal criteria of reliability. This finding is in agreement with that of Paton (1964) who records that none of the 70 displays personally observed by him became visible until the sun was at least 6.75° below the horizon. Similarly, only a few apparently genuine occurrences of noctilucent cloud have been made in the period under study when the solar depression was greater than 15°. Indeed, 96% of our high reliability observations were made when the solar depression lay in the range of 7° – 14°. The generally accepted range of 6° – 16° would include all but two of our 1053 high reliability events.

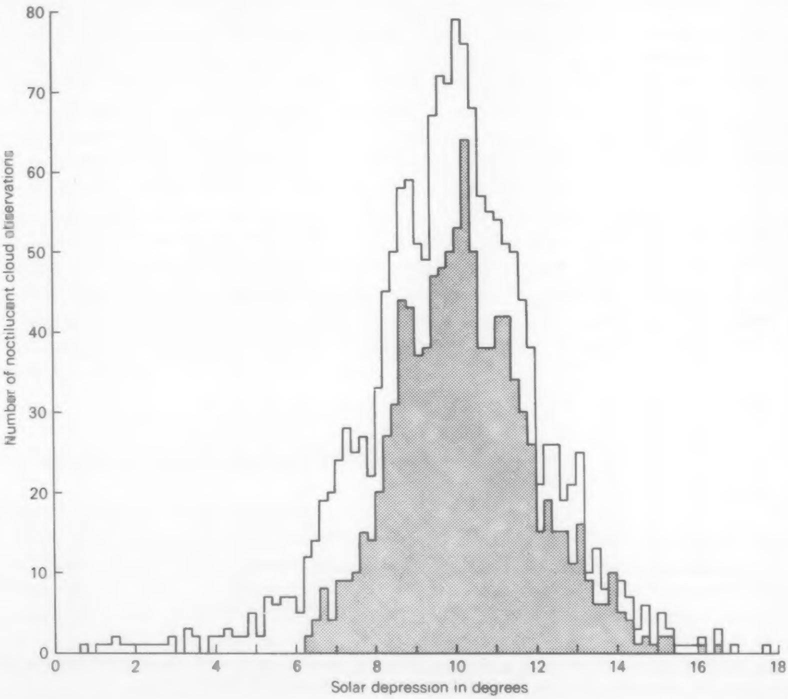


Figure 2. The incidence of noctilucent cloud observations at 0.2° intervals between 0° and 18° of solar depression. The lower shaded 'curve' gives the distribution of the reliable observations which had height values within 1 SD of the average. The upper 'curve' gives the distribution of all observations including those with height values in excess of 3 SD of the average.

(c) *Height of noctilucent cloud*

Noctilucent cloud occurs within a very narrow height range close to the temperature inversion layer at the mesopause. Most authorities quote this range as 82.4 km (±1 km) with extreme limits of 75 km and 93 km. The average height of the clouds over the past 17 years derived from all our observations was 83.76 km and from the high reliability results alone, 83.87 km. At first sight, these results may appear

to be highly satisfactory but, with ISD = 15.04 km, the range for the high reliability results was 68.83 — 98.91 km which is a much wider scatter than that indicated by the best modern practices. From these results one can only conclude that the good average heights obtained are due to the cancelling out of random errors in the large sample under study and that, as is generally agreed, good parallactic photography is still a necessary prerequisite for accurate height determination in any one display.

(d) *Distribution of noctilucent cloud observations in latitude*

In the 17-year period of the summary, only one report of noctilucent cloud was received from below latitude 50°N and that proved to have a poor reliability rating by our criteria. Similarly, only ten reliable observations were received from latitudes higher than 60.5°N. Thus 99% of our reliable reports came from between latitudes 50°N and 60.5°N. Even within these latitudes, Fig. 3 shows that there is a

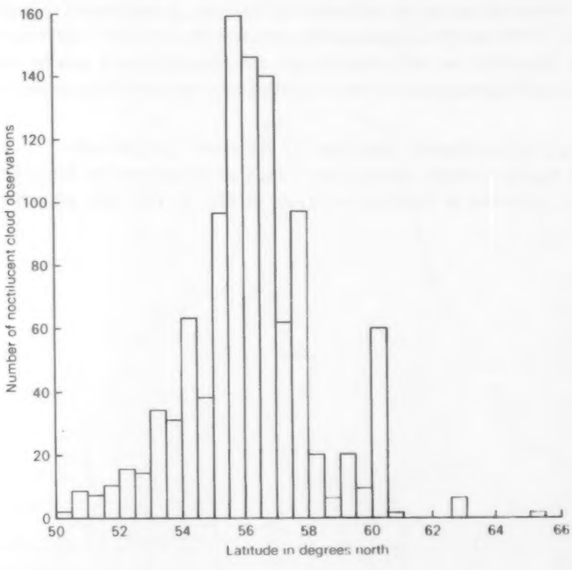


Figure 3. Histogram showing the distribution of noctilucent cloud observations with latitude.

decided peak in noctilucent cloud observations centred around 56°N with 76.3% of the reports coming from the 4° zone between latitudes 54°N and 58°N and more than half (51.6%) from the 2° zone between latitudes 55°N and 57°N. These findings can be readily explained in terms of the solar depression during the main noctilucent cloud season (12 May to 1 August). Between these dates at 56°N and thereabouts, the sun lies within the critical depression limits of 6° – 16° for a large part of the summer night. At 61°N the time spent within the critical limits begins to fall off sharply to zero at 66°N approximately. However, noctilucent cloud may in principle be seen for short periods after the main season from latitudes higher than 66°N when the solar declination is lower and the solar depression therefore greater.

Although the sharp decrease in observations from latitudes over 61°N is to be explained mainly in terms of solar depression, the population density and the consequent lack of observers in these regions is almost certainly an important contributory factor. A further population effect may also be present in Fig. 3. Fogel (1966) finds that the peak latitude for noctilucent cloud observations in the North American continent is 57.5°N. It may be that our value of 56°N is a genuine difference for the west European region over the period of study, but it more probably reflects a bias to the lower latitude (56°N) of the Central Lowlands of Scotland which have a high density population and a network of active observers reporting on a regular basis.

It is important to note that the site of observation does not necessarily define the geographical location of the clouds which may lie as much as 7° to the north of the observer when the clouds extend down to the northern horizon. However, the exact geographical location of the clouds may be determined by simple spherical trigonometry as outlined by Simmons (1977). When this was done for our high reliability observations at the extremes of latitude, it was found that all the clouds lay within the range of 51.8°N – 72°N which is appreciably narrower than the 45° – 80° band implied by Bronshten and Grishin (1976). However, as indicated above, noctilucent cloud can be observed from latitudes above 66°N, but no such sightings have been reported over western Europe in the period under review.

(e) *Seasonal incidence of noctilucent cloud and its variation with latitude*

The incidence of highly reliable noctilucent cloud observations by date of occurrence during the period under study, is shown at five-day intervals in Fig. 4. The vast majority of displays occurred

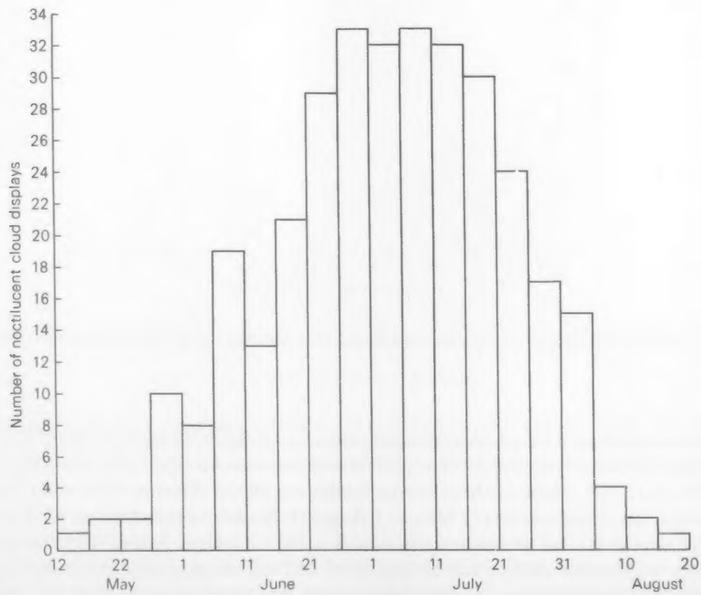


Figure 4. Histogram showing the seasonal incidence of noctilucent cloud displays.

between 27 May and 10 August with the median date at 4 July. The normal distribution of noctilucent cloud about this date and the two-week seasonal lag in the maximum from the summer solstice to 4 July are unremarkable, having been well documented in previous reviews. In contrast, Fig. 5 shows the seasonal incidence of the high reliability observations divided on the basis of latitude into the three zones 50°N – 54°N, 54°N – 58°N and 58°N – 62°N. The vast majority of observations were made from the 54°N – 58°N zone with a median date about 4 July. However, the majority of observations from the 50°N – 54°N zone were recorded before 1 July whereas the majority from the 58°N – 62°N zone were observed after that date. These conclusions, which are again in agreement with past findings, have given rise to the view that the clouds 'move' northwards during the season. However, this northward movement is readily explained by the fact that the region which most frequently satisfies the critical conditions for illumination of the clouds ($d = 6° – 16°$) moves north as the solar declination falls after the summer solstice.

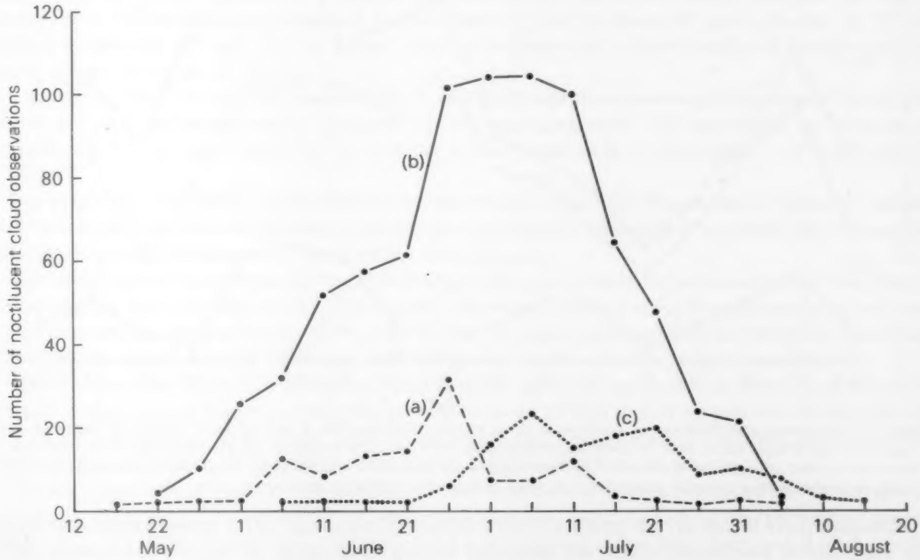


Figure 5. The seasonal distribution of noctilucent cloud observations at different latitudes. Curve (a) 50°N to 54°N, (b) 54°N to 58°N, (c) 58°N to 62°N.

(f) *Year-to-year variation in the incidence of noctilucent cloud*

The annual incidence of noctilucent cloud in the years 1966 to 1982 is shown in Fig. 6. The upper curve (a) gives the total number of nights for which reports of noctilucent cloud were received accompanied by sufficient information to test the reliability of the observations. The intermediate curve (b) gives the number of nights with noctilucent cloud observations that satisfied the criteria of reliability. The lower curve (c) gives the number of nights with major noctilucent cloud displays (nights with at least six reliable reports from at least three different observers). Curve (c) was drawn to exclude the possibility that a large number of random minor events might mask a periodicity in the less frequent

major displays. All three curves show a steady fall in the incidence of noctilucent cloud from a maximum in 1967 to a pronounced minimum in 1970. A similar but less pronounced minimum is evident in the summer of 1980 following a progressive fall from the maximum year 1977. A number of interesting points arise from Fig. 6. Firstly, the proportion of observations rejected as unproven seems to remain fairly constant from year to year. Secondly, the periodicity of noctilucent cloud shown by the high reliability results is also discernible in the major display curve (c). Thirdly, the minima of 1970 and 1980 follow closely on the solar activity maxima of 1969.7 and 1979.9 respectively.

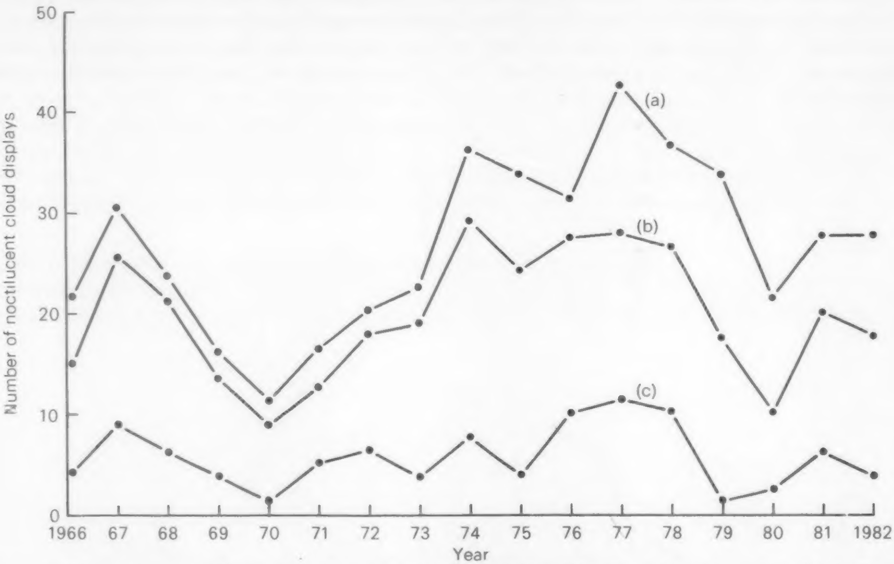


Figure 6. The year-to-year incidence of noctilucent cloud displays 1966 to 1982. Curve (a) total number of nights for which reports of noctilucent cloud were received accompanied by sufficient information to test the reliability of the observations, (b) total number of nights with observations that satisfied the criteria of reliability, (c) total number of nights with major displays (nights with at least six reliable reports from at least three different observers).

Although these results do not provide direct evidence of any causal effect between solar activity and the incidence of noctilucent cloud, the suggested inverse relationship of the two phenomena can be explained in terms of the nature of these clouds. According to the condensation hypothesis, they consist of hydrated protons of the general structure $H^+ (H_2O)_n$ which aggregate and precipitate when the temperature at the mesopause falls to about 160 K. At solar maximum when the mesopause temperature is relatively high, it is less likely to fall to this critical level but, at solar minimum when the mesopause temperature is generally lower, it is more likely to do so. However, it should be stressed that although the observed results are consistent with our present concepts of noctilucent cloud, the existence of an inverse relationship between solar activity and noctilucent cloud still requires confirmation from direct or more detailed circumstantial evidence.

4. Discussion and conclusions

Systematic observation of noctilucent cloud was initiated in this country in 1949 by Paton who built up a network of observers based on the Balfour Stewart Auroral Laboratory in Edinburgh. Paton's (1964) review of this program was followed by an extension of the network and by the introduction in 1966 of a more detailed format for recording observations. Without these two developments, this statistical study would not have been possible. In general terms, the main features and characteristics of noctilucent cloud noted over the period of Paton's early work have continued to be observed throughout the years of the present study. However, our more analytical approach using high reliability observations has enabled us to define the circumstances surrounding the appearance of noctilucent cloud rather more precisely.

Although it has been recognized that noctilucent cloud can, on rare occasions, extend overhead and into the southern sky, it is more typically observed at low elevation along the northern horizon. Paton (1964) found that 'it is only occasionally that the clouds are observed in central Scotland at elevations greater than 10° above the northern horizon'. However, in the period 1966 to 1982, 36.7% of our reliable observations had an apparent elevation greater than 10° (but less than 20°) and a further 11.1% had elevations between 20° and 30°. As a rule, only the brightest and most extensive of displays gave an upper border in excess of 45°.

The critical limits of solar depression at times of noctilucent cloud also require some revision, at least for the period of the present study. The generally accepted range of 6° – 16° is probably too broad as the majority (96.0%) of clouds were visible when the solar depression lay in the range 7° – 14° with the peak at 10.45°.

For height determination, our findings do no more than concur with the general consensus of opinion that 'one-sided' methods are virtually valueless for determining the height of any given display and that good parallactic photography is required for that purpose.

The distribution of noctilucent cloud in latitude also seems to have been more restricted than in earlier studies. During 1966 to 1982 all the clouds lay between 52°N and 72°N which is a much narrower range than the generally accepted 45°N to 80°N. The southern limit is probably close to the true value. However, the upper limit of 72°N may well be too low by reason of a 'population effect'.

The seasonal incidence of noctilucent cloud over the period of study followed the usual pattern of activity in that the vast majority of events occurred between 27 May and 10 August with the median date of 4 July showing a lag of two weeks after midsummer's day. Observations from lower latitudes tend to occur earlier in the season and those from higher latitudes later in the season.

Finally, our study of year-to-year variation in the incidence of noctilucent cloud shows two distinct minima in the years 1970 and 1980. A previous minimum was noted by Paton (1967) extending over the years 1957 and 1958. In contrast, two maxima for noctilucent cloud have been noted in the period covered by the present study from 1964 to 1967 and from 1974 to 1978. While these results support an inverse relationship between annual sunspot number and frequency of noctilucent cloud occurrence, they yet fall short of confirming it. It should be borne in mind that over the period of the survey there have been changes in the geographical area covered by observers and in the extent to which automatic photography throughout the night has been used to identify cloud occurrences, also year-to-year variations in the extent of interference caused by tropospheric clouds. Such systematic and casual influences may well have obscured a clearer relationship between solar activity and noctilucent cloud formation.

Acknowledgement

We are grateful to Dr A.P. Conway, Department of Natural Philosophy, University of Glasgow, for computer processing some of the results.

References

Bronshten, V.A. and Grishin, N.I. 1976 Noctilucent clouds (ed. I.A. Khvostikov). Keter Publishing House. Jerusalem.

Fogel, B. 1966 Noctilucent clouds. *Geophys Inst Rep*, UAG. R-177. University of Alaska.

Gadsden, M. 1982 Noctilucent clouds. *Space Sci Rev, Dordrecht*, **33**, 279–334.

Jesse, O. 1885 Auffallende Abenderscheinungen am Himmel. *Meteorol Z*. **2**, 311–312.

Paton, J. 1964 Noctilucent clouds. *Meteorol Mag*, **93**, 161–179.

Simmons, D.A.R. 1977 The noctilucent cloud display of 18–19 June 1976. *Weather*. **32**, 240–248.

List of annual reports used as a source of observational data in chronological sequence.

Paton, J.	1967	*Meteorol Mag.*	**96**,	187–190.
	1968	*Ibid.*	**97**,	174–176.
	1969	*Ibid.*	**98**,	219–222.
	1970	*Ibid.*	**99**,	184–186.
	1971	*Ibid.*	**100**,	179–182.
	1972	*Ibid.*	**101**,	182–185.
	1973	*Ibid.*	**102**,	171–174.
McIntosh, D.H. and Hallissey, M.	1974	*Ibid.*	**103**,	157–160.
	1975	*Ibid.*	**104**,	180–184.
	1976	*Ibid.*	**105**,	187–191.
	1977	*Ibid.*	**106**,	181–184.
	1978	*Ibid.*	**107**,	182–187.
	1979	*Ibid.*	**108**,	185–189.
	1980	*Ibid.*	**109**,	182–184.
	1981	*Ibid.*	**110**,	109–112.
	1982	*Ibid.*	**111**,	122–125.
	1983	*Ibid.*	**112**,	245–249.

Notes and news

Extracts from an ancient file

The following extracts from an old file retained at Shoeburyness of correspondence between the Senior Meteorological Officer, a Branch at Headquarters (M.O.5.), and the Superintendent of Experiments at Shoeburyness tell their own story.

M. O. 5.

I attach herewith a report on the accident to the Kite Balloon this morning, in confirmation of telephone message.

I should be glad if this station could be supplied with two or three pairs of rubber gloves for use in attaching streamers to the cable and while working the winch. I think this will be a safeguard.

Meteorological Office,
New Ranges,
Shoeburyness.
28/3/1922.

M. O. 5.

I regret to inform you that the Kite Balloon at this station was struck by lightning this morning at 0959 G.M.T. The balloon itself was entirely destroyed together with 5000′ of cable. The Dobson and Richard Meteorographs were recovered beyond hope of repair.

At the time, the balloon was stationary with 5000 feet of cable paid out. The weather was overcast with passing showers: it was raining at the time of the accident. The wind was very moderate, the tensionmeter recording about 5 cwt. Myself and one of the balloon squad were in the winch house and the remainder of the squad were in the balloon shed. The balloon itself was hidden, being above the low drifting cloud. Suddenly the cable appeared to become a mass of flame and almost simultaneously there was a loud explosion. I saw the cable in the winch house suddenly drop slack and, on running to the loading off gear, I saw that there was no cable beyond the tensionmeter. It was clear that a violent discharge of electricity had passed down the cable and destroyed the balloon.

On investigation, the remains of the Dobson Meteorograph were found in a field about ½ mile away but no trace of the balloon was discovered nor were any fragments of it seen to fall. Later on, a villager gave the information that the main guys and Richard Meteorograph were in a field about a mile distant from Landwick from whence they were duly recovered. Some burning fragments of the balloon were smouldering near by. The hemp core of the burnt cable was lying across country — the metal part of the cable was entirely burnt away leaving the hemp core unscathed. A curious exception to this was found in the short length of cable lying between the attachments of the Dobson Meteorograph frame. This short piece of cable was intact, the discharge having apparently passed through the frame in preference to the cable.

Fortunately no one was injured. Had the accident occurred at 4000′ instead of 5000′, a tragedy might have taken place as at this point, we attach a streamer to the cable.

M. O. 5.

Confirming my telephone conversation of this morning (28 Nov. 1924), I beg to state that during a heavy gale last night, the skeleton of the balloon hangar was blown down and destroyed.

The wind had been increasing steadily and from 0200 this morning to the time of writing this report, it was well above gale force. I have been unable to ascertain at what time the collapse took place but I should imagine that it was between 0400 and 0500. The mean wind speed throughout this hour was 77 f/s. with a maximum gust of 98 f/s. at 0440. There appears to have been about a dozen gusts of 90 f/s. or over.

The shed collapsed by tilting over and folding up from front to back. It must have been a very violent gust which finally brought about its fall. The iron pickets holding the front iron guys were wrenched out of the ground as well as some of the wooden pickets. The steel hook of one of the iron strainers attached to the wire guys was smashed in half. The wood work is very much smashed and is now of little use — indeed some of it appears to be quite rotten.

Fortunately, the canvas cover had been entirely removed and the roof sheets were lying on the floor of the shed. As far as I can at present ascertain, no M.O. stores have been damaged but the four derelict Scammel winches are beneath the wreckage and a 40 ft. ladder belonging to the S. of E. has been broken.

Before clearing anything, I am endeavouring to secure some photographs of the wreckage. Then I will raise sufficient of the wood to rescue the canvas from the floor of the shed. It will be necessary, however, to clear the remains from the four winches as Messrs. Spencer may call for these any day now. These winches are under the thickest part of the heap and while we are freeing them, it would appear best to clear the whole of the pile. If you concur in this, will you please telephone me in the morning so that I can get all hands at work on it.

It is of interest to mention other local damage due to this gale. Two large elms on the New Ranges have been blown down and there is a good deal of smaller damage to fences and slated roofs.

Superintendent of Experiments (Shoeburyness)

I have been informed that it is the intention of the Air Ministry to abandon the Kite Balloon work at this station.

In order that the necessary data with regard to upper air temperatures should be available for use at this station for Range and Accuracy and other trials, two aeroplanes with the accompanying personnel have been attached to Eastchurch Aerodrome and flights will be made from that station as a matter of routine. The data thus obtained will be available for use here in working up meteorological reports.

This will probably be more satisfactory from your point of view as it will ensure that results are obtained on a much greater percentage of occasions and that there will be no enforced periods of inactivity on account of repairs to the balloon or hangar.

Meteorological Office,
New Ranges,
Shoeburyness.
8/12/24.

Honour

In the New Years Honours List for 1983 it was announced that Mr C.W.G. Gazzard, Professional and Technology Officer IV, Meteorological Office, Bracknell, had been awarded a British Empire Medal.

THE METEOROLOGICAL MAGAZINE

No. 1334 September 1983 Vol. 112

CONTENTS

NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General, Meteorological Office, London Road, Bracknell, Berkshire RG12 2SZ and marked 'For Meteorological Magazine'.

The responsibility for facts and opinions expressed in the signed articles and letters published in this magazine rests with their respective authors.

Applications for postal subscriptions should be made to HMSO, PO Box 276, London SW8 5DT.

Complete volumes of 'Meteorological Magazine' beginning with Volume 54 are now available in microfilm form from University Microfilms International, 18 Bedford Row, London WC1R 4EJ, England.

Full-size reprints of out-of-print issues are obtainable from Johnson Reprint Co. Ltd. 24-28 Oval Road, London NW1 7DX, England.

Please write to Kraus Microfiche, Rte 100, Millwood, NY 10546, USA, for information concerning microfiche issues.

Printed in England by Robendene Ltd., Amersham, Bucks.
and published by
HER MAJESTY'S STATIONERY OFFICE

£2 monthly
Dd. 717701 K15 9/83

Annual subscription £26.50 including postage
ISBN 0 11 726938 7
ISSN 0026-1149